APPLICATION OF OPTICAL FIBER CURRENT SENSORS TO UNDERGROUND CABLES

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ABSTRACT

Optical fiber current sensors based on the Faraday effect were expected for a long time as compact and high performance current sensors in place of conventional current transformers. However, widespread practical application of them has not been realized yet, because of complex means necessary for securing stable characteristics. Tokyo Electric Power Company solved the problem, with use of a special fiber as the sensing element, and by constructing sensing system matching with properties of the sensor fiber. The developed sensors are immune from outer environment such as electromagnetic noise, vibration, and temperature changes. Also the sensors are capable of high-speed response and of long distance signal transmission. Furthermore, the sensor head of the devices are compact and flexible. Therefore, by using the developed sensors, current can be detected easily and stably by only encircling the sensor fibre around the current conductors, such as existing power cables.

Taking notice of these strong points, the authors developed a fault section locating system for underground power cable lines applying the sensors, and also developed a fault point locating system using the sensors. The developed systems are applied practically. In this paper, the optical fiber current sensor is introduced firstly. Then the paper describes the fault section locating system and its practical application to a 66kV cable line, and also describes the fault point locating system and practical application of it to a 275kV line.

KEYWORDS

Faraday effect, optical fiber, current, sensor, fault location, cable

INTRODUCTION

Current monitoring is a basic and important technology for the control, protection, and supervision in most facilities sustaining industry and community, such as power facility. Traditionally, the current transformers consist of iron cores and windings have been used for the measurement. However, the followings are recognized as problems of them.

a. Current transformers are heavy and bulky.
b. It is difficult to install them to thick and/or high voltage conductors, and also difficult to attach them to existing apparatus.
c. The measurement signals are influenced by electromagnetic induction noise.
d. Measurement of large current, especially including low frequency component, is difficult.

As a hopeful solution for the problems, in the 1960s, the optical current sensor based on the Faraday effect was proposed **(1).** After that, in the 1980s, a method using optical fiber as the Faraday sensor element (optical fiber current sensor) is proposed **(2).** Then, research and development of the method has been carried out at many institutes for a long time. However, widespread practical application of the sensors has not been realized yet, because of the complex means necessary for securing stable characteristics of the sensors. One of the serious problems was that the polarization of light in the fiber used as the sensing element is affected by mechanical stress in it through the photo-elastic effect.

Tokyo Electric Power Company (TEPCO) developed a novel optical fiber current sensor in which such problems are solved. The developed sensor indicates excellent features such as easiness of stable current detection by only encircling the light and flexible sensor fiber around the current conductor. Taking notice of such features of the sensors, the authors developed a fault section locating system, and also developed a fault point locating system for underground power transmission cable lines, using the sensors.

This paper reports the result. Firstly, sensor technologies are expressed concerning principle, key technologies for securing characteristics, design of a sensor applying the key technologies, and characteristics of that. Then, the fault section locating system is described. Practical application of it to a 66kV line is also reported. Finally, the fault point locating system and practical application of it to a 275kV line is described.

2. OPTICAL FIBER CURRENT SENSOR

2.1 Principle of Operation

When a light beam passes through a transparent medium in a magnetic field, polarization of the light is rotated in proportion to the field. This effect is called “Faraday effect”, and is the basic principle of the optical fiber current sensors. The rotation angle is indicated by the following equation,

$$\theta_F = VHL \qquad [1]$$

where,